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MILITARY STANDARDIZED TRANSPORTATION
AND MOVEMENT PROCEDURES
DETAILED MANIFEST DATA
STORAGE REQUIREMENTS

THESIS

Philip L. Isbell, Captain, USAF

AFIT/GLM/LSP/91S-32

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Wright-Patterson Air Force Base, Ohio

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**MILITARY STANDARDIZED TRANSPORTATION
AND MOVEMENT PROCEDURES
DETAILED MANIFEST DATA STORAGE REQUIREMENTS**

THESIS

**Presented to the Faculty of the School
of Systems and Logistics
of the Air Force Institute of Technology
Air University
In Partial Fulfillment of the
Requirements for the Degree of
Master of Science in Logistics Management**

**Philip L. Isbell, B.S.
Captain, USAF**

September 1991

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Preface

This study sought to determine the data storage requirement for airlift data in a much expanded transportation information system environment. Using the systematic approach of Dr. Benjamin Ostrofsky's *Design, Planning and Development Methodology*, a set of feasible solutions was derived. Detailed examination of the solutions will provide an optimal data storage system capable of handling the increasing data traffic requirements of emerging transportation information systems within the Department of Defense.

I would like to thank my advisor, Lieutenant Colonel Dick Peschke, who helped me "keep my head, when all around me were losing theirs." His support and encouragement, when much else gave way, turned what could have been a trying and tedious experience into a life long learning endeavor by the application of "a little morphology to the madness." Thanks to John Rausch for his friendship, commiseration, and for just being a generally all around good egg.

A very special note of thanks goes to my wonderful wife Carol, whose support, patience, and chocolate chip cookies saw me through the most difficult days. Thank you Heather and Ian for helping Dad keep his priorities straight. And most importantly of all, thank you Lord for making all things bright and beautiful.

Philip L. Isbell

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Abstract

The purpose of this study was to develop a set of useful solutions to the problem of storing and processing data generated by transportation data processing systems within the Department of Defense. The amount of data within the Global Transportation Network (GTN) will significantly increase due to the expansion of the Joint Operational Planning and Execution System (JOPES). Intransit visibility of troops and equipment during contingencies is the driving factor behind the increased level of data required by JOPES.

The methodology used conducted a needs analysis of the problem, which was defined as an insufficient amount of storage capacity for the amount of anticipated data required by JOPES. A feasibility study was completed that organized relevant information into a more meaningful analysis. A solution set was derived by assessing needs within boundaries imposed by the activities which any system must perform to solve the stated problem. The cyclical nature of the analysis indicated that the medium by which the capacity would be transferred to the GTN must also be considered. Over 300,000 potential solutions to the problem were formulated. Further research into the methodology's preliminary activities will reduce the number of potential candidates to the optimal solution.

**MILITARY STANDARDIZED TRANSPORTATION
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I. Introduction

General Issue

A lack of automated processes and systems integration in existing Department of Defense (DOD) transportation information systems has resulted in the lack of visibility on troops and cargo deployed during contingency operations. National Command Authorities and subordinate agencies may not have accurate information regarding movement of forces during directed operations. Military Airlift Command (MAC) transportation information systems are unable to provide USTRANSCOM adequate intransit visibility of cargo and equipment deployed by airlift during contingency operations (30:20-21).

The problem is exacerbated by the existence of separate procedures for resupply and deployment type movements. Current procedures for mobility operations supporting deployments are not automated. Procedures for resupply type movements are automated; however, each functional area uses a different computer system tracking different numbers representing parts, equipment, and cargo moved by airlift.

Supported units are concerned with stock numbers and delivery dates. Supply activities track requisition numbers. Transportation activities track transportation control numbers, priorities, and age of cargo by destination. Operations agencies track mission numbers.

The gap that exists between functional area computer systems within the transportation component commands and between other Services and USTRANSCOM is the cause of the inability of the Joint Operations Planning and Execution System (JOPES) to provide accurate, detailed logistics information regarding movement of forces by air during directed operations.

JOPES combines the Joint Operational Planning System (JOPS) and the Joint Deployment System (JDS) into a single user system (9:2-1). The JOPS is the planning portion of the system and the JDS is the execution element of the system. The JDS consists of the personnel, procedures, directives, communications systems, and electronic data processing systems necessary to directly support time-sensitive planning and execution.

Information systems have historically been built to satisfy a particular base, major command, or Air Force need. These systems vary in complexity and utilize a variety of hardware and software. They have become separate processors of information and storage facilities, or islands of automation (31:18).

Islands of automation should be viewed as boundaries between individual computer systems carrying information. This information is not automatically shared with other systems and, in some cases, must still be transferred manually between systems. Data such as asset identification, location and time of entry into the defense transportation system, or warehouse location are confined to a single system. However, this information could be useful to other systems in the logistics pipeline.

These gaps between islands of automation result in capability shortfalls. Because of these gaps, information is not easily shared or transferred. Some system functions remain semiautomated, manual and paper intensive (31:20). Other automated processes are not fully in place and adequate integration does not exist between systems in order to make intransit transportation information visible to all logistics systems.

This results in the complete inability to track individual items. Present information systems do not provide the opportunity to look within consolidated shipments to provide in-transit information to the line item level of detail. Specifically, current transportation documentation does not list individual items included in a shipment (31:22).

Systems evolution within air transportation functional areas has led to the design and continuing implementation of new systems. These systems are intended to provide the

links between the islands of automation. As more capable systems are designed, more data elements are being required in the information gathering process. New transportation data processing systems storage capacity may need to double in capacity (18).

Specific Problem

The quantity of detailed information on air shipments required by developing transportation information systems is expanding as new systems are designed. It is questionable whether current systems can handle the surge in volume (13:2). The amount of data storage capacity required to store and process the amounts of information required by the Joint Operation Planning and Execution System is insufficient.

Research Objectives

The focus of the research was to develop a set of systems which will have the storage capacity and accessibility necessary to permit detailed air transportation data information to be provided to the JOPES database. This database is developed during the execution of contingency plans and is used to provide supported commands with detailed logistics information. The data inputs required by the JOPES database and the data outputs which could be generated by proposed transportation systems were examined to determine feasible levels of storage capacity.

Scope

The proliferation of information systems across the Department of Defense has caused difficulties in transforming data from one system to another. As the number of proposed systems has increased, so has planned system inter-connectivity and the requirement for more data. In some instances, the transformation of data requires human extraction and re-input into follow-on systems. This study begins with a look at USTRANSCOM's global transportation network and its potential for providing detailed information requirements. Airlift transportation information systems within the network were examined to determine their potential to provide JOPES with the required level of detailed logistical data.

II. Literature Review

Introduction

The United States Government has considered employing military force in more than 200 international crises over the past 35 years. Each of these crises require planning and sometimes executing military contingency operations. The United States' National Command Authorities must be capable of deploying forces rapidly and efficiently regardless of the size of the contingency (20:18).

The Joint Operation Planning and Execution System (JOPES) is the conventional command and control system being developed for national and theater level decision makers and their staffs. It will incorporate the policies, procedures, reporting structure, and the underlying information systems used to plan and conduct joint military operations. It will support operations ranging from the development of plans to the direction and sustainment of forces during crisis (20:vi).

Global Transportation System

The Global Transportation Network (GTN) under development by the United States Transportation Command (USTRANSCOM) is a transportation information system which will integrate the information processing capability of the civilian and Department of Defense (DOD) transportation communities (8:23-24). The GTN will provide JOPES

transportation manifest summary information and detailed Military Standard Transportation and Movement Procedures (MILSTAMP) manifest data. JOPES will provide the GTN force and resupply requirements for the operation plan in effect (12:1). The GTN is intended to be a system of information systems (8:24).

Computer based information systems have been in use in the logistics environment since 1954 (23:65). Unfortunately, most automation since then within the DOD transportation system has been on an ad hoc basis and has primarily dealt with historical data (9:6). In the past decade, significant advances have occurred in the information processing capability of transportation activities in an attempt to keep pace with an expanding industrial capability. As of 1984, there were 37,000 motor carriers operating 1.4 million tractor-trailer units and the number of major scheduled airlines had increased to 148 (23:5). The information systems developed to cope with more carriers handling more passengers and cargo have tended to be oriented toward processing information specific to a particular mode. Transportation activities of all types have developed their own systems and policies to meet their own needs (2:28).

The most efficient and effective use of airlift, sealift, and land transportation resources requires an overview of intransit cargo and personnel from origin to destination. Driven by the Defense Transportation System's

dependence on civilian transportation companies for 80 percent of all surface and 50 percent of all strategic airlift (2:26), USTRANSCOM's mobility management mission dictated that an integrated transportation system usable in both war and peace be developed (8:23).

By networking existing systems together, USTRANSCOM plans to gain access to transportation information regardless of where the data may be stored. Eighty to 85 percent of all GTN data will come from civilian transportation systems (2:26). The first step to networking, identification of each transportation system by the data it processes, will be relatively easy, since the most popular method of grouping information systems within the civilian sector has been by the problem area a particular computer application addressed (28:66). However, there are at least 200 major civilian transportation information processing systems to assess and many have little in common or the ability to interface. There will be a significant degree of difficulty developing a common database consistent across the network to achieve the standardization on which the success of the GTN rests (2:27).

In the early 1980s, the Military Traffic Management Command (MTMC) attempted to analyze the network of national defense transportation infrastructure and determined that the military will be 90 to 95 percent dependent on commercial transportation in the event of a mobilization.

Analysis of defense use of highways, railroads, and ports could no longer be done without the use of computers (6:2). With the computers, or in this case the system of computers, comes the additional problem of multiple levels of security. In addition to the normal DOD security requirements, data from competing vendor's information systems will have to be protected (2:26). In the event of mobilization, this becomes increasingly difficult as priorities and procedures change during the shift from peace to war (8:24).

The planning of lift requirements to ensure the most efficient and effective use of limited airlift resources would be tremendously improved upon implementation of the GTN (2:26). The over 100 separate major logistics information systems within DOD and the 200 civilian transportation information systems, without further expansion being necessary, contain or process all the information necessary to provide visibility over all transportation assets available and any particular unit's cargo movement requirements. Successful implementation of logistics information systems within the civilian transportation community has been difficult to achieve (7:370). Where success was achieved, a large degree of coordination between distribution and other profit centers was present (7:373).

The GTN will connect to and interact with a large number of separate and distinct databases. Given the

massive size of the network, any coordination could be considered an achievement (2:26).

Information systems have been used within the transportation community for almost thirty years. During this entire period, no single agency has been able to influence the overall direction of systems development (2:23). The proliferation of systems in use has a wide degree of hardware configurations, operating environments, and applications programs (8:24). A reduced force structure will increase the need for more efficient mobility management as fewer defense resources will be required move more quickly over greater distances in response to global contingencies.

The effective use of the defense transportation system will be dependent in large part on the degree of information available to theater Commander-in-Chiefs and national decision makers as the transportation system is shifted to move the right people and cargo to the right place at the right time (8:26). The GTN will combine intransit visibility of passengers and cargo with the most effective use of airlift, sealift, and land transportation (2:26).

Transportation Coordinator's Automated Information for Movements System

The Transportation Coordinator's Automated Information for Movements System (TC-AIMS) is the computers, hardware, software and other systems used by transportation

coordinators in all service activities within the joint deployment community in support of the deployment process (20:1). Existing transportation systems will be integrated with new systems the Services develop to form the total TC-AIMS (20:3).

TC-AIMS generated data is the foundation for updating the JOPES with actual shipment information. It provides the basis for USTRANSCOM'S GTN to derive transportation data to the transportation control number level of detail (21:1). At the service and major command level, TC-AIMS will provide close to real-time information on unit move requirements, status, and the departure of units during both the planning and execution phases of deployments (20:15). USTRANSCOM does not own the TC-AIMS systems or control any of the data inputs to these systems. It is entirely dependent on the Service's systems and subsystems to provide the required movement information necessary to update JOPES (13:1).

Automated Transportation Systems

Three automated systems support transportation; the Cargo Movement Operations System, the Enhanced Transportation Automated Data System, and the Integrated Intelligent Logistics Database (30:8). The Cargo Movement Operations System (CMOS) will be the major segment of the Air Forces's TC-AIMS. It will allow the DOD transportation community to use the same processes trained on in peace during contingency operation plan execution (31:1). As

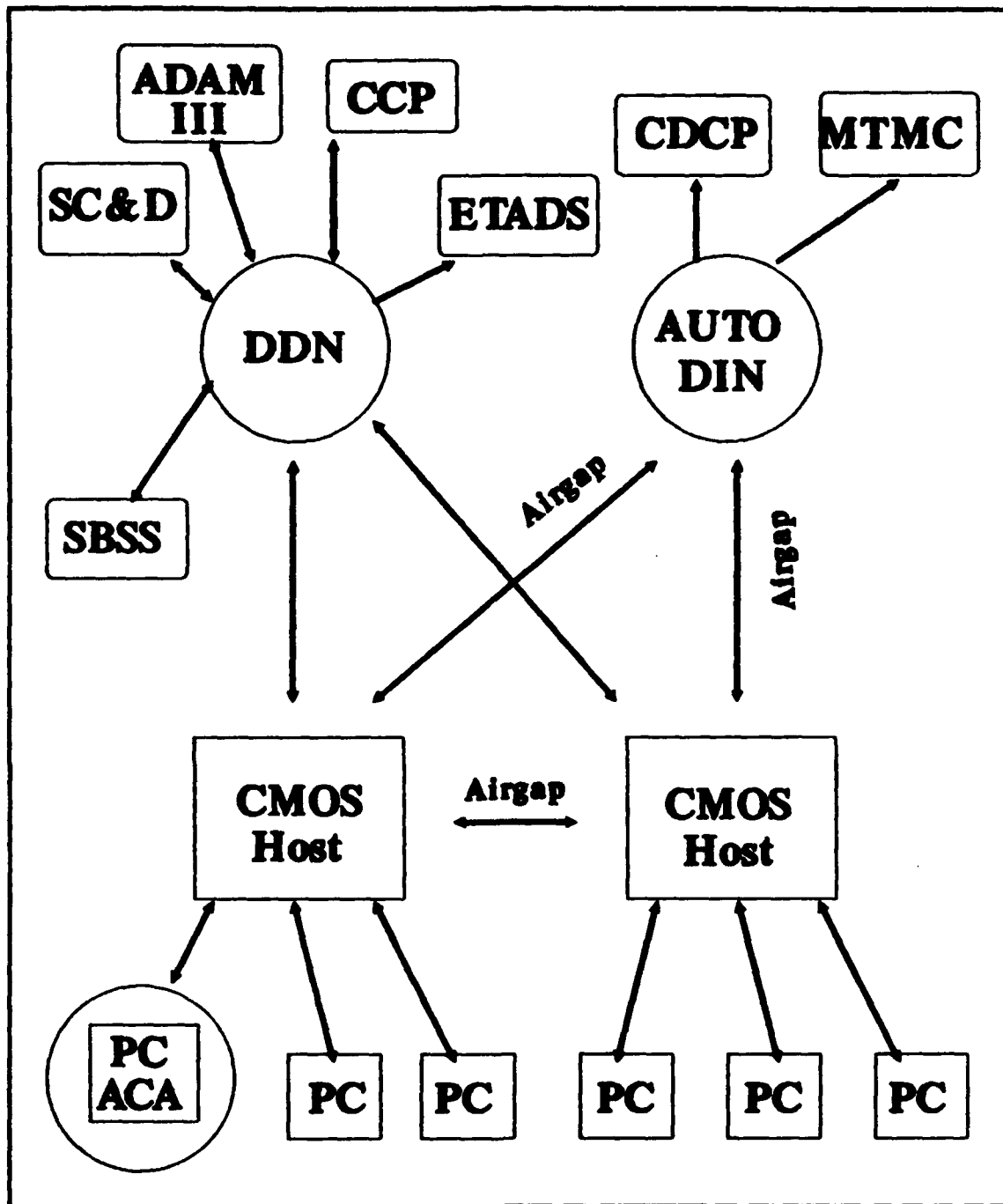


Figure 1. CMOS Integration (29:13)

depicted in Figure 1, CMOS will establish the automated links essential for the integration of DOD and commercial sector logistics systems.

The Enhanced Transportation Automated Data System (ETADS) supports Air Force Logistics Command (AFLC) activities associated with the defense transportation system by controlling AFLC Continental United States (CONUS) transportation systems and by monitoring the movement of Air Force cargo overseas (30:8). The Air Force Logistics Intelligence File (AFLIF) is an integrated intelligent logistics database that will integrate data generated by Military Standard Requisition and Issue Procedures (MILSTRIP) and Military Standard Transportation and Movement Procedures (MILSTAMP). In effect, it will combine supply and transportation data (30:9). The AFLIF will link Military Traffic Management Command (MTMC), MAC, and base level systems with ETADS.

Intransit Visibility

Together with CMOS, ETADS would allow visibility of materiel shipment status within the logistics pipeline (30:10). CMOS adds the capability to process cargo and passengers in a unit move environment and report the movements (31:2). All information reporting is accomplished in accordance with DOD Instruction 4500.32R, Military Standardized Transportation and Movement Procedures, as MILSTAMP data sets (21:1). This satisfies the TC-AIMS requirement for the capability to transfer inter-service movement data (31:3).

The primary sources of information on asset visibility are the Transportation Control Number (TCN) and the National Stock Number (NSN). The TCN tracks individual or grouped assets and the NSN is the tool used to gain visibility over assets in storage (30:16). Each unit shipped is controlled by a unique 17 character TCN as shown in Table 1 (11:G-3).

Table 1. *Transportation Control Number (11:G-3)*

TCN Position	Explanation
1	Service Code (A-Army, F-Air Force, M-Marine Corps, N-Navy).
2-8	Army activities will enter a unit identification code (UIC) beginning with TCN position 2 and putting zeros in positions 7-8. All other services will enter Joint Deployment System unit line numbers (ULN) beginning in TCN position 2 and filling any remaining unused positions with zeros.
9-10	Service Use. (Requires data entry, do not leave blank. Use zeros if not data available).
11-14	Shipment, increment, or serial number.
15	Unit Cargo TCN indicator (A zero must always be entered).
16-17	Split/partial shipment or complete shipment unit indicator.

Information Flow

Data originates with the creation of a requisition in base supply (30:15) or as a data string from base movement requirements systems converted to a MILSTAMP compatible

format (31:3). When the shipment arrives at the shipping activity, CMOS generates a shipment status record and updates the Standard Base Supply System (SBSS) to reflect that CMOS has taken control of the shipment. A unit move TCN is distinguished from all others by the location of a zero in the fifteenth position (31:3-4). When another Service passes through an Air Force installation, that Service's movement requirements will be passed in MILSTAMP format from their TC-AIMS to CMOS (31:3).

Once the cargo is entered in the CMOS database, shipment planners can take shipment consolidation and mode selection action. CMOS technicians will be able to change/add/delete shipping data including outsized cargo information, freight rate codes, National Motor Freight Classification, Uniform Freight Classification, and the Stock Number Users Directory (31:5). If the shipment is air eligible and going overseas, CMOS sends an advance notice to the controlling agency for that modal type shipments. The system used to manage this requirement in the Air Force is the ETADS. Once ETADS determines the cargo is air eligible, the movement requirement is passed electronically to MAC's communications gateway (31:5-6).

The communications gateway is used to access MAC's Headquarters On-Line System for Transportation (HOST). The HOST is the central database repository for the Consolidated Aerial Port Subsystems (CAPS) located at MAC terminals worldwide (4). CAPS consists of two subsystems; the Aerial

Port Documentation and Management System (ADAM III) and the Passenger Automated Check-In System (PACS). ADAM III and CMOS have 70 percent commonality, while PACS and CMOS have only a 10 percent commonality (5).

ADAM III/HOST is in a star configuration. ADAM III is used to document and process the cargo arriving at MAC aerial ports for shipment. ADAM III sends the transactions it processes to the HOST via dedicated communication lines. When one ADAM III station sends a down line manifest to another ADAM III station, the transaction comes to the communications gateway at HQ MAC and then gets routed to the down line station (4). CMOS procedures will remain the same with all data transmitted to the HOST in MILSTAMP format. The number of locations transmitting data, however, will increase from 26 to over 400. Over 1200 locations will generate MILSTAMP data used in moving cargo through the defense transportation system (21:1).

Due to approaching equipment obsolescence and to standardize transportation procedures, ADAM III functions will be incorporated into CMOS. If ADAM III were not rolled into CMOS, the current ADAM III system would have to be replaced in the near future and would still have to interface with CMOS. This would create double work at MAC's aerial ports since people would have to input the same basic information into both systems. The MAC unique functions have been identified for incorporation into CMOS's air freight module (4; 5).

Transportation Information Flow to JOPES

MILSTAMP procedures have been changed to require the same procedures be used for processing unit move cargo as are used in daily movements. The applicable Unit Line Number from JOPES has become a required entry into the unit move TCN. The NSN is a required data entry on transportation control and movement documents and will be required as additional TCN data in the next change to MILSTAMP procedures (30:32).

Inclusion of the ULN in the TCN provides JOPES visibility through the HOST and GTN over specific increments of a unit's movement. The ULN data in JOPES can be used by forward elements to determine status of forces in-theater, to perform unit level analysis, and to gain visibility of cargo being airlifted by MAC (17:3). The addition of NSN data opens visibility to shipment contents. It allows decision makers the option of rerouting shipments to meet higher priorities and can be used to locate specific items at other locations within the system (14:1,3).

JOPES' scheduling and movement subsystem makes transportation information available via JOPES and the GTN in peacetime as well as during predetermined plan execution. The data required to provide detailed manifest information to the system will expand as additional requirements are identified (12:2). The increasing levels of data per shipment, as shown in Table 2, will cause an expansion in the number of characters per air cargo manifest. Cargo

Table 2. Data Requirements for GTN - JOPES Interface (12:3)

Characters	Manifest Data Elements
17	Transportation Control Number (TCN)
13	National Stock Number (NSN)
35	NSN Nomenclature
3	MILSTAMP Water Commodity Code
1	MILSTAMP Dangerous Cargo Code
1	MILSTAMP Air Commodity Code
1	MILSTAMP Special Handling Code
4	MILSTAMP POE (GELOC)
4	MILSTAMP POD (GELOC)
10	STONS
10	MTONS
10	Square Feet
5	Number of Pieces
1	JOPES Supply Class
1	JOPES Supply Sub-class
6	Consignor
6	Consignee
3	Project Code
TBD	Passenger Name
8	Passenger SSAN
30	Reserved for Expansion

database files could double in size (25:1). A doubling of the data transmitted will effect the speed at which any data

communication system can provide that data to systems within the GTN (27:55).

Transmission Mediums

Data communication is relatively slow compared to the computer. Some applications and their usual operating ranges are listed in Table 3. The slow speeds are due to

Table 3. *Link Speeds and Uses* (3:10)

Speed in Bits	Typical Uses
0-600	Telegraph, older terminals; telemetry
600-2400	Human operated terminals; personal computers
2400-19,200	Applications requiring fast response and/or throughput; some batch and file transfer applications
32,000-64,000	Digital voice; high-speed applications some video
64,000-1,544,000	Very high speed for multiple users; computer-to-computer traffic; backbone links for networks; video
greater than quality 1,544,000	Backbone links for networks; high video; multiple digital voice

the use of telephone lines, which were the most convenient and readily available means when industry first began to link computers with terminals and other computers. Voice transmission between people does not require the speed associated with data transmission, so the telephone line was not designed for fast transmission between high speed computers (3:10). The speed of a data transmission is

described in bits per second. Common mediums and their transmission speeds are listed in Table 4.

Table 4. *Mediums and Common Transmission Speeds (27:56)*

Medium	Common Transfer Rates (bps)
Private line	300, 1200, 2400, 4800, 9600, 19200, 38400, 5600, 64000, 80000
Switched Connection	300, 1200, 2400, 4800, 9600, 19200
Leased Line	2400, 4800, 9600, 19200, 56000, 64000
T1, T2, T3, T4	1.5M, 6.3M, 46M, 281M
Coaxial Cable	1M, 2M, 10M, 50M, 100M (over 400M potential)
Fiber Optics	over 2 Gbps
Microwave	to 45M
Broadcast radio	9600
Satellite	to 50M

Transmission mediums can be classified as either guided or unguided. In guided media, electromagnetic waves are guided along a physical path such as a twisted pair of wires, coaxial cable, or optical fiber. Unguided mediums provide a means of transmitting electromagnetic waves but do not guide them. Radio, microwave and satellite transmissions are sent through the air, an unguided medium (26:22).

The transmission path between two devices is called a direct link if the signal is sent directly from a

transmitter to the receiver without going through an intermediate device other than an amplifier or repeater to increase signal strength. A guided transmission medium is point-to-point if it provides a direct link between two devices and those are the only two devices sharing the medium (26:22-24).

Two important characteristics of an electromagnetic signal are amplitude, frequency, and phase. The amplitude is the value of a signal at any time. The frequency is the inverse of the period, or the number of repetition of the period per second; it is expressed in cycles per second or hertz (Hz) (26:24).

The range of frequencies in a signal is called its spectrum. The width of the spectrum is called the absolute bandwidth. Within the absolute bandwidth, most of the energy is contained in a narrow band of frequencies. This band is the signal's effective bandwidth. There is a direct relationship between data rate and bandwidth. The higher the data rate of a signal, the greater its bandwidth. The greater the bandwidth of a signal, the higher the data rate that can be transmitted using that particular signal (26:26). The greater the bandwidth the greater the capacity. The bandwidth between 10^3 and 10^4 is 9000 Hz ($10,000 - 1000 = 9000$). The bandwidth between 10^7 and 10^8 is 90,000,000 Hz ($100,000,000 - 10,000,000 = 90,000,000$) (3:41).

The terms analog and digital roughly correspond to continuous and discrete. For example, voice and video are continuously varying patterns of intensity. Digital data takes on discrete values; examples are text and integers (26:29). Text, in character form, is not easily stored or transmitted by data processing and communications systems, which are designed for binary data. A number of codes have been devised in which characters are represented by a sequence of bits. The most commonly used code in the United States is the American Standard Code for Information Interchange (ASCII) code (26:30).

ASCII encoded characters are always stored and transmitted using 8 bits per character. A block of 8 bits is referred to as a byte. A digital signal is a sequence of voltage pulses that may be transmitted over a wire medium. A constant positive voltage level may represent binary 1 and a constant negative voltage level may represent binary 0 (26:34). The greater the bandwidth of the signal, the more precisely it represents a digital pulse stream (26:37).

A digital signal can be transmitted only a limited distance before attenuation endangers the integrity of the data. To achieve greater distances, repeaters are used. A repeater receives the digital signal, recovers the pattern of 1's and 0's, and retransmits a new signal.

Both long distance telecommunications facilities and intra-building services are being converted to digital transmission. With the use of repeaters rather than

amplifiers, the effects of noise and other signal distortions are not cumulative. It has become economical to build transmission links of very high bandwidth, including satellite channels and optical fiber (26:39).

The rate at which data can be transmitted over a given communication path, or channel, under given conditions, is referred to as the channel capacity. The highest signal rate that can be carried is twice the bandwidth of the signal (26:43). So, for a given bandwidth, the data rate can be increased by increasing the number of different signals (26:44). If the data rate were doubled, the bits would be more tightly packed together and the same passage of noise might destroy two bits. For a constant signal and a constant noise strength, an increase in data rate increases the error rate (26:46).

The three most important guided media are twisted pair, coaxial cable, and optical fiber. Their characteristics are listed in Table 5. Twisted pair is the most common

Table 5. *Three Common Guided Mediums* (26:47)

Transmission Medium	Total Data Rate	Bandwidth	Repeater Spacing
Twisted Pair	4 Mbps	250 KHz	2-10 km
Coaxial Cable	500 Mbps	350 MHz	1-10 km
Optical Fiber	2 Gbps	2 GHz	10-100 km

transmission medium for both analog and digital data. It has primarily been a medium for voice traffic between

subscribers and their local telephone exchange office. Digital data traffic can be carried over moderate distances with repeaters used every two to three kilometers. Data rates of about 64 Kbps are achievable using digital signaling. However, in long distance trunking applications, data rates of 4 Mbps have been achieved. Twisted pair is limited in distance, bandwidth, and data rate (26:47).

Coaxial cable is the most versatile transmission medium. It is used for long distance telephone and television transmission, television distribution, local area networks, and short-run system links (26:50). It can support a large number of devices and transmit both analog and digital signals over distances from a single building to a complex of buildings. Coaxial cable has better frequency characteristics than twisted pair and can be used more effectively at higher frequencies and data rates (26:51). Data rates of up to 100 Mbps are common and rates as high as 800 Mbps have been achieved with a repeater spacing of 1.6 kilometers (26:53; 27:45).

The advantages of coaxial cable are a high data rate, an immunity to distortion from noise, the capability to add additional stations, and a reasonable cost over short distances. There are some significant disadvantages. Coaxial cable is not a very secure medium. Taps are relatively easy to make and difficult to detect. Whenever distances are great, attenuation becomes a problem. Costs

increase relative to due to the greater number of repeaters and length of cable (27:45-46).

Optical fiber transmits a signal encoded beam of light by means of total internal reflection (26:54). Optical transmission has a very large information capacity. Bandwidths in the range of 500 Mhz are not unusual (3:128). It enjoys considerable use in long-distance telecommunications and its use in military applications is growing. Its price continues to decline while its performance continues to improve. Data rates of 2 Gbps over tens of kilometers have been demonstrated. This compares to the practical maximum of hundreds of Mbps over 1 kilometer for coaxial cable and just a few Mbps over 1 kilometer for twisted pair (26:53). Repeater can be spaced as far as 20 to 30 miles apart (3:128).

Optical fiber is not vulnerable to interference, impulse noise, or cross talk. The fibers do not radiate energy, causing little interference with other equipment and providing a high degree of security from eavesdropping. Fewer repeaters mean lower cost and fewer sources of error. A 68 kilometer link without use of a repeater can operate at 8 Gbps with very low error rates (26:54).

There are two major undersea optical cables spanning the Atlantic and Pacific. The trans-Atlantic system handles the equivalent of 40,000 voice band transmissions (3:127). A voice grade channel is defined as a band of 4000 Hz (3:40). The cable spans 3607 nautical miles and terminates

at Tuckerton, New Jersey, Widemouth, England, and Penmarch, France. The trans-Pacific system spans 8000 nautical miles from an area north of San Francisco to Hawaii, Guam, Japan, and the Philippines (3:127).

Microwave transmissions are limited to line-of-sight. Long distance transmissions are achieved by stringing together microwave stations at no more than 30 miles apart. Microwave can support high data rates over long distances. However, its greatest application is in providing digital transmission in small regions. Microwave transmission offers speed and cost effectiveness, but suffers from interference from other radio waves and a high degree of susceptibility to eavesdropping (26:56,57; 27:48,49).

The principle difference between radio and microwave is that radio is omnidirectional while microwave is a focused beam. Radio waves suffer a lot of interference from obstructions created by land, water, and other natural or physical objects (26:60).

A communication satellite is a microwave relay station. It is used to link two or more ground stations. The satellite receives transmissions on one frequency, amplifies or repeats it, and transmits it on another frequency. A satellite can have a number of frequency bands called transponders (26:58; 27:50). Each transponder has a transmission rate of approximately 50 Mbps. Although satellite technology has a high transmission rate, it

suffers from propagation delay due to the large distances the signal must travel (27:52).

Transmission Speeds

A wide range of transmission speeds are available. Low speed circuits transmit at rates under 100 bps and high speed circuits at over 100 Mbps. Within a given medium, higher data transmission rates require more sophisticated equipment, which usually means higher costs. The response time and the aggregate data rate determine the speed of a medium. The aggregate data rate is the amount of information that can be transmitted in a given unit of time. Transmission time and processing time determine the response time (27:55).

Data communications applications use either switched connections or leased lines. Switched connections are established when a station dials a telephone number with which it needs to communicate. Since the telephone company cannot guarantee exactly which path or switching equipment a connection will use, the speed and quality of the switched connection is limited. Most switched connections operate at speeds of 300, 1200, 2400, 4800, 9600, or 19,200 bps. Digital data transmission technology will permit speeds of up to 56,000 bps with switched connections. Switched lines are used when there is only a small amount of data to be transmitted or when many stations must be contacted for short periods of time (27:43).

Leased lines are used when the connection time between locations is long enough to cover the cost of leasing or if speeds higher than those available with switched lines must be attained. These lines can be conditioned by the telephone company to provide lower error rates and increased transmission speeds. Conditioned leased lines typically operate at speeds of up to 64,000 bps. Very high speed services are designated T1, T2, T3, and T4 and offer transmission rates of 1.5, 6.3, 46, and 281 Mbps, respectively. The cost of a leased line is a function of the distance covered, the transmission speed of the line, and the susceptibility to error (27:44).

Error Rates

Data transmitted correctly from one computer often arrives incorrectly at the destination computer. The data can be damaged enroute, such that the binary 1s and 0s representing codes and symbols are misinterpreted by the receiver. On long distance carriers, data transmitted at 1.2 Kbs experiences a moderate bit error rate of 1 in 10^5 to a very poor 1 in 10^3 . In other words, we may expect one bit to be damaged in every 1000 to 100,000 bits transmitted. Black cites studies that indicate a telephone line experiences an incidence of 0.7 to 142.6 errors in every one thousand blocks sent, with each block consisting of 1000 bits. The degree of accuracy required determines the tolerable error rate (3:10-11).

Transmission impairments on a medium can destroy portions of the data stream. Response time and throughput are dependent on the type of medium used (3:117). The use of dedicated circuits and high quality media can substantially reduce the error rate. Data link controls offer specific protocols to control the data flow between stations. They check for transmission errors at the receiver, attempt to correct the error at the receiver, and request the sender to retransmit the damaged data. Optical fiber offers superior performance over conventional media with a typical error rate of 10^{-9} versus 10^{-6} in metallic cables (3:12,129).

As a practical matter, it makes sense to measure the incremental cost necessary to make incremental gains in error control (3:372). Table 6 lists the approximate undetected bit error rates for frames of differing sizes. For a frame of 1122 bits (128 bytes * 8 bits of user data + 3 bytes * 8 bits of packet header + 5 bytes * 8 bits of internal network header + 4 bytes * 8 bits of frame header and trailer = 1122 bits, rounded to 1000), the probabilities of an undetected error are approximately $5 * 10^{-10}$ for a link operating in a relatively poor 10^{-4} bit error rate (3:373).

Virtual Circuits and Datagrams

At the interface between a station and network node, a network may provide either a virtual circuit or datagram

Table 6. *Approximate Undetected Bit Error Rates (3:375)*

Bits in Frame	Bit Error Rate			
	10^{-4}	10^{-5}	10^{-6}	10^{-7}
100	3×10^{-8}	3×10^{-9}	3×10^{-10}	3×10^{-11}
300	1×10^{-7}	1×10^{-8}	1×10^{-9}	1×10^{-10}
1000	4×10^{-7}	4×10^{-8}	4×10^{-9}	4×10^{-10}
3000	1×10^{-6}	1×10^{-7}	1×10^{-8}	1×10^{-9}
10000	4×10^{-6}	4×10^{-7}	4×10^{-8}	4×10^{-9}
30000	$\approx 10^{-5}$	$\approx 10^{-6}$	$\approx 10^{-7}$	$\approx 10^{-8}$

service. With a virtual circuit interface, the user performs a call request to set up a virtual circuit and uses sequence numbers to exercise flow control and error control. The network attempts to deliver the packets in sequence (26:252).

With datagram service, the network only agrees to handle packets independently. Internally, the network may construct a dedicated path between endpoints or not. The internal and external design do not need not to coincide.

In an external virtual circuit with an internal virtual circuit design, the user requests a virtual circuit and a dedicated route through the network is constructed. All packets will follow that same route.

In an external virtual circuit with an internal datagram design, the network handles each packet separately. Different packets for the same virtual circuit may take different routes. However, the network tries to deliver

packets to the destination in sequence. Usually, the network will buffer packets at the destination node so that they may can be placed in the correct order for delivery (26:252-253).

In an external datagram with an internal datagram design, each packet is treated independently from both the user's and the network's point of view. An external datagram with an internal virtual circuit design makes little sense, since the cost of a virtual circuit implementation would be incurred without any of the benefits (26:254).

The major advantage of a datagram mechanism is its robustness and flexibility. The datagram allows efficient use of the network with no call set up or disconnection and no need to hold up packets while a packet in error is retransmitted. The advantage of a virtual circuit mechanism is that it minimizes per packet overhead since routing decisions are only made once per virtual circuit. It can provide end-to-end sequencing, flow control, and error control. Virtual circuits provide sequenced deliver of packets. The Defense Data Network (DDN) is internal and external datagram (26:254-255).

Defense Data Network

DDN is a packet switching network grouped into two major functional areas; the backbone network which consists of the packet switches and the trunks between them and the

access network which consists of the user access lines connected to the backbone (3:297). Satellite and microwave links, cable and commercial carriers are used to provide packet switching to packet switching connections (10:1-4). The host trunks can operate at 9.6 to 56 Kbits. Each host system can be directly connected to one or more packet switches by one or more links (3:297). The DDN has been designed to provide survivability, security, and privacy. Much of the equipment is configured with electromagnetic pulse protection in the form of electromagnetic shielding, line isolation circuits, and surge suppressing components. Some of the nodes are configured with an uninterrupted power supply. Several of the nodes are also configured with redundant equipment to prevent a single failure from isolating a node. DDN is a dynamic routing network and adjusts itself to any damage without disrupting service to the surviving station. Distributed routing allows the nodes to automatically route the data around damaged, congested, or destroyed links and switches. DDN provides extensive monitoring of the system and enables a graceful degradation in order to route around damaged or congested areas (3:297). It provides secure traffic transmission by using end to end encryption and other security measures. The network is actually composed of two separate networks, one of which is for classified use only (3:298).

III. Methodology

The design, planning, and development methodology of Dr. Benjamin Ostrofsky of the University of Houston was followed to develop a set of feasible solutions to the problem statement. The system designer can turn to the fields of engineering design and adaptive design to help formulate the structure required to sequence the decisions which must be made in the development of an accurate set of requirements (22:10).

Background

Historically, designs tended to develop over long periods of time, each change adding small improvements to preceding designs. The slow rate of change reduced the risk of making errors in the design process. Asimow termed this process as "design by evolution" (1:2).

In the first half of this century, the increasing complexity of technology quickly widened the gap between the initial idea for a process and its actual utilization (16:12). In what Asimow calls "design by innovation" a new scientific discovery is made and a body of technical knowledge quickly develops around the new discovery. The application of the new technology may require a complete break with past practices. At least initially, the outcome of these new practices is subject to an increased risk of technical error (1:2). Hall defines the process between the

first step of basic research and the utilization of a design as "organized creative technology". System engineering narrows the gap between technological discoveries and their application (15:3).

Increasing complexity brought about an increasing number of interactions between the multiple facets of manufacturing. These interactions involve many technical, scientific, and communication problems involving individuals with varying backgrounds, levels of authority, and skills (15:5,16:12).

In the 1930s, the Radio Corporation of America (RCA) recognized a need for a systems approach in the development of a television broadcasting service. After World War II, the RAND Corporation developed the idea of systems analysis, which became the foundation of systems engineering. However, the use of the term "systems engineering" was first used in the early 1940s by the Bell Telephone Laboratories (15:7).

Hall lists seven objectives in seeking to define systems engineering (15:12).

1. Provide management with the information needed to control the development program
2. Formulate long range plans as a framework for connecting individual projects
3. Balance the development program to assure progress and the best use of manpower and other resources
4. Develop objectives for projects and know the present needs and anticipate the future needs of the organization

5. Ensure the best use of technology
6. Carry out each operation in the most efficient manner possible

Systems engineering, however, does have its drawbacks. Difficult to verify value judgements can be found in its objectives. Objectives exist in hierarchies. One objective is only a means to some higher objective. Where objectives in a given project start and end is largely a matter of personal judgement. Systems engineering functions are not unique. They can be common, in whole or in part, with many other functional areas. Therefore, it can be argued that different people with differing backgrounds, working in different areas, could be pursuing the same objectives in their own way (15:11).

Differing attacks on the same problem stem from the differences between philosophical approaches to the problem. The philosophy itself does not set out the actions to be taken in solving a particular problem. Rather, it spells out the principles, concepts, and methods which could pertain to a whole set of similar or related problems. Philosophy leads to theories and detailed methods of applying them (1:3-4). In his book *Introduction to Design*, Morris Asimow states that the philosophy of engineering design has three major parts, a set of consistent principles, an operational discipline, and a feedback apparatus (1:4).

Asimow developed fourteen principles to be followed in the design process. These principles required the design to be in response to some individual or social need, that the design result must be the optimal alternative, and that the design meet significant physical, financial, and other design constraints (1:5-6). These principles are the foundation of Asimow's design morphology, or progression or a design from the abstract to the concrete (1:6; 24:3).

The morphology of design refers to the study of the sequential structure of design projects (1:12). The result of Asimow's efforts was an orderly sequence of required decisions which produced an effective plan to meet the stated need (24:3).

Applied Methodology

The work of Morris Asimow and Arthur Hall was done in response to the need for improved planning for complex projects (24:3). Ostrofsky recognized the need to assemble the various philosophies in a sequential course in design, planning, and decision making. His work is based largely on Asimow's earlier work organized into a less technical and more manageable methodology (24:x,3).

Ostrofsky states a project begins with a feasibility study in order to establish a solid base from which to build ideas in depth as one progresses through the morphology. The iterative nature of the feasibility study is exhibited in Figure 2. The purpose of the feasibility study is the

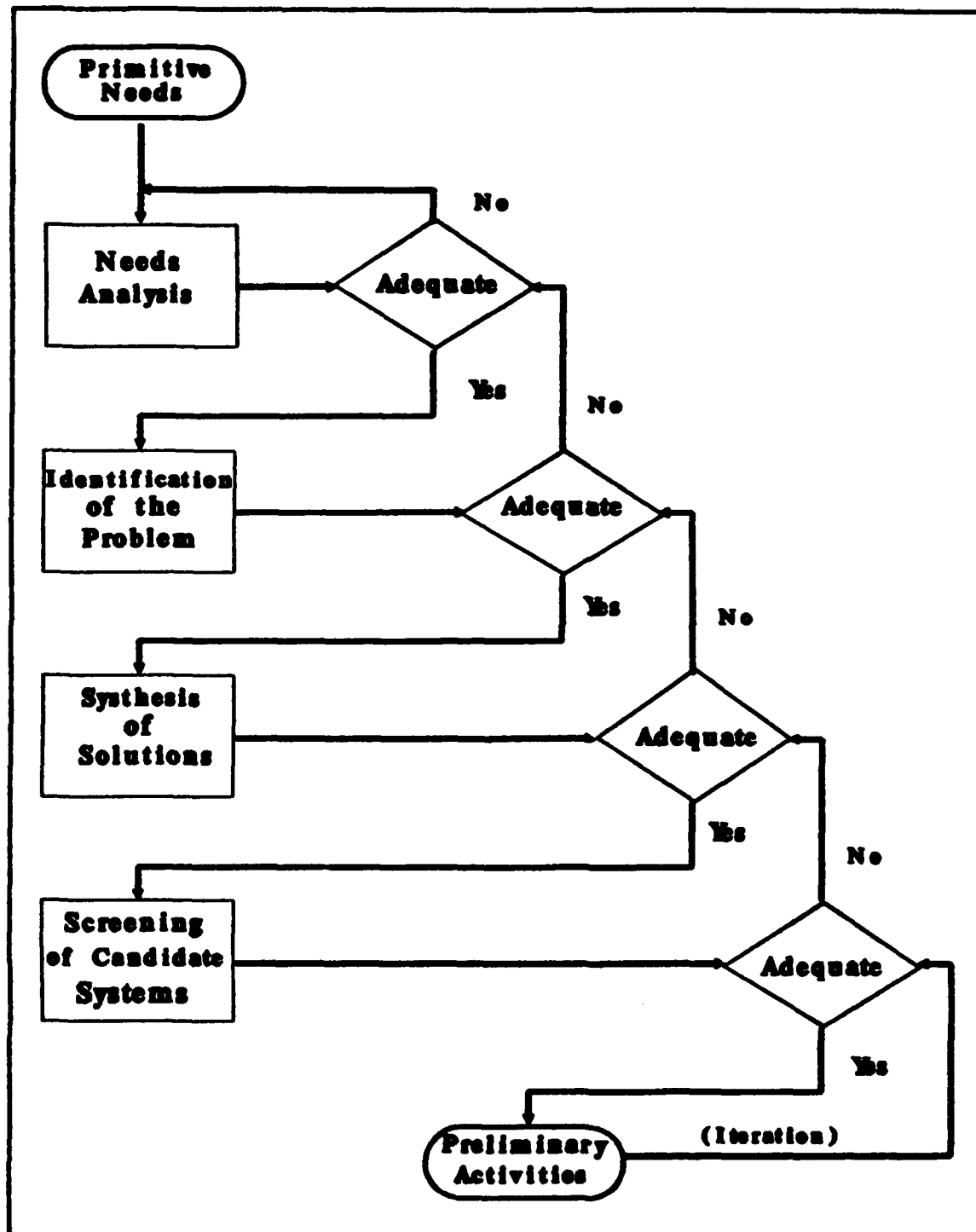


Figure 2. Feasibility Study (24:28)

achievement of a set of useful solutions to the problem.
The major activities in this phase are the establishment of

need and the explicit definition of the problem to be solved by the plan or design. The feasibility study blends and screens solutions and if no useful solutions emerge, the problem is determined to be not feasible. The completed study provides the problem needs, an identification of the planning or design problem, and a set of useful solutions (24:18-19).

The Design, Planning, and Development Methodology recognizes that the number and complexity of design alternatives often make the design problem impossible for the decision maker to resolve without a structured method for organization (22:12). Ostrofsky structures the design process into two phases; the Production-Consumption Phase and the Primary Design-Planning Phase which are illustrated in Figure 3.

The Production - Consumption Phase is the actual operation of the system within the context for which it was designed. It consists of:

Production - the transformation of goods or services into something more useful.

Distribution - the transfer of the production product to the user.

Consumption - the process of operating the system.

Retirement - the activities necessary to remove the system from operation (24:9-15).

The Primary Design-Planning Phase is when the designer identifies, selects and develops plans for a solution which

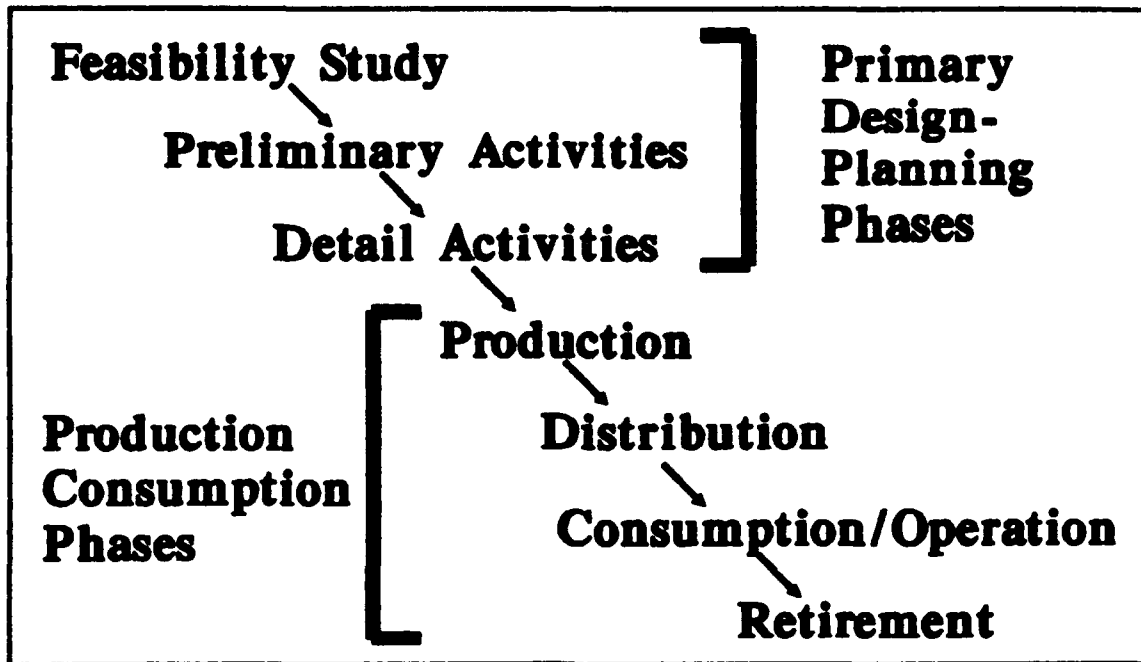


Figure 3. *Design Activity Phases* (22:12; 24:18)

will meet the needs of the user during the Production-Consumption Phase (24:17-18). The three elements of the Primary Design-Planning Phase are:

Feasibility Study - results in a set of useful candidate systems.

Preliminary Activities - identify the best system from the set of candidate systems previously identified.

Detail Activities - the activities associated with the formulation of the plans for the implementation of the optimal system (24:18,29,70,155).

The feasibility study is the focus of this research. It has four phases:

Needs Analysis - produces a general statement of needs which the project must satisfy (24:31).

Problem Identification - the needs are analyzed in terms of inputs to and outputs of the system (24:35).

Synthesis of Solutions - the piecing together of activities to meet the needs established during the needs analysis (24:45).

Screening of Candidate Systems - the elimination of solutions, candidate systems, which physically, economically, or financially are not feasible (24:55).

A problem cannot be successfully solved, or any system successfully designed, by simply following the logic of Ostrofsky's morphology. Strict adherence to the design methodology does not, in and of itself, guarantee a successful solution (24:4). It is more a structured problem analyzer than a problem solver (16:15).

Conclusion

A review of the literature germane to the expansion and evolution of transportation information systems revealed that data contained within repositories in existing transportation systems may be insufficient. As the planned inter-connectivity of new systems grew, the perceived demands for more transportation data increased respectively. A system of transportation systems is envisaged which will connect all transportation data providers and users within the DOD.

The data storage capacity necessary to support the GTN cannot be defined in terms of just capacity, but must also

address the time it takes using systems to receive requested data and the time it takes for the data storage repository to process the data into and out of its memory. Therefore, a system of storage designed to meet the requirements of the information system it supports must have sufficiency of memory, responsiveness, and processing time.

As the many of the information systems within the GTN are still in the planning stages, the exact requirements for storage capacity are yet to be formally determined. Ostrofsky's methodology, with its emphasis on logic and simplicity is well suited to the design of a set of storage systems which could meet this future need.

IV. Feasibility Study

The purpose of the feasibility study is to develop a set of useful solutions to meet the needs of the Global Transportation Network for an expanded data storage capability. The storage system must be of sufficient capacity to quickly and accurately process the significantly increased levels of transportation data projected over a linked network of transportation systems (24:29).

Needs Analysis

Within the context of the system the GTN portends to become, any conceptualized data storage repository must meet the need of any information system within the GTN for transportation data. It must also concurrently meet the demand any on line activity may generate for storage capacity of new data. The needs analysis seeks to clarify and define the needs of the system under consideration. Its cyclical nature is shown in Figure 4. It provides the justification for proceeding further with the expenditure of time, effort, and other resources (24:31).

The increased level of systems interconnectivity of the GTN will permit a much higher rate of information exchange between systems in the network (30:20-22). The need for transportation data by JOPES stems from the effort to provide the necessary logistics information to field commanders and national decision makers during

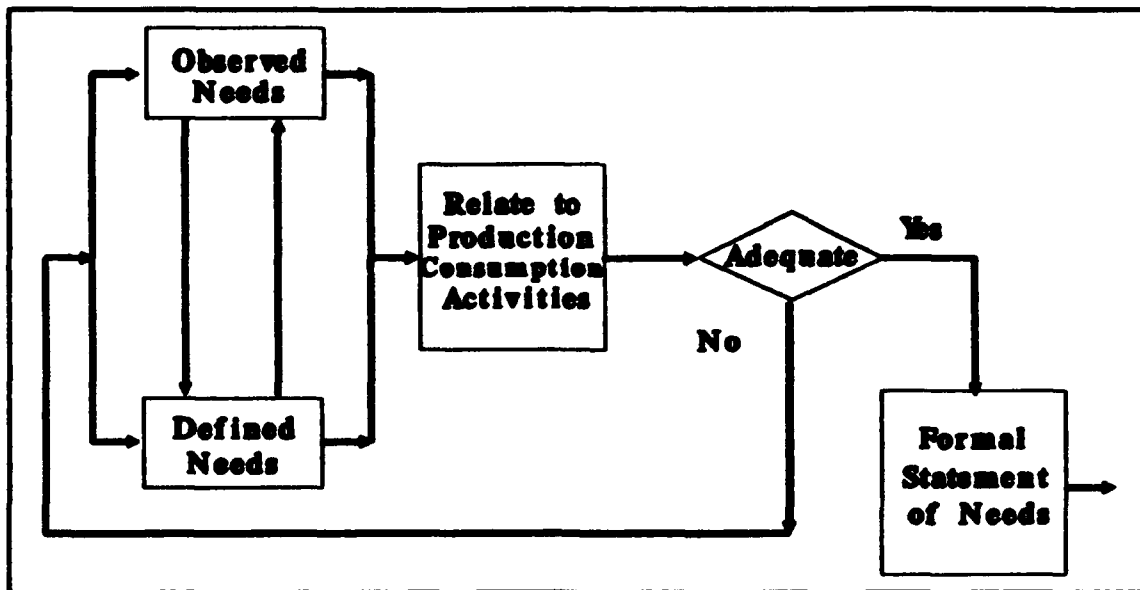


Figure 4. *Needs Analysis* (24:31)

contingencies. In order to eliminate the confusion which occurs during the shift from normal day-to-day procedures to those used during actual contingencies, JOPES is being developed to function as both a peacetime and wartime information system (12:1,3-4; 20:vi). The amount of data to be collected to support the increasing need of decision makers for information could double the size of current files (25:1). The amount of computer storage and degree of responsiveness to system data transfer demands may increase greatly.

A worst case scenario that would generate the greatest amount of data from airlift sources would have the entire strategic airlift fleet, including the C-17 and the Civil Reserve Air Fleet (CRAF) Stage III, perform one round trip mission per 24 hour period with two full uploads and

downloads per mission. It would consider only pallet movement, causing the maximum generation of TCNs. It would count the tactical airlift C-130 as making one round trip per day with 8 uploads and downloads per trip. Each prime record would have an average of 8 updates before the shipment reaches the consignee (19). The total number of transactions generated is shown in Table 7.

Table 7. Total Airlift Transaction Generation

Type A/C	No. A/C	Pallets Per A/C		Pallets Positions Per A/C Type	
C-17	210	X	16	=	3360
C-141	234	X	13	=	3042
C-5	110	X	36	=	3960
CRAF	127	X	36	=	4572
Strategic pallet positions available					
					14934
Uploads or downloads				X	2
Updates				X	8
Strategic lift generated transactions					238944
C-130	492	X	6	=	2952
Uploads or down loads				X	8
Updates				X	8
Tactical lift generated transactions					188928
Total transactions per day					427872

Each transaction is the record of a prime TCN. The prime TCN is the control number assigned to the oldest shipment in the highest priority of a particular pallet. Each pallet contains an average of 11 TCNs (32). Each TCN

is part of the expanded manifest data set required to support JOPES through the GTN. The expanded data set contains 138 characters including the TCN (12). Therefore, the number of characters requiring storage, on a worst case basis, is 649,510,000. The total storage requirement at 8 bits per character is 5,196,100,000 bits and is detailed in Table 8.

Table 8. *Total Storage Requirements*

Total transactions per day		427872
Average TCNs per pallet	X	11
Total TCN transactions per day		4706592
Expanded manifest character requirements	X	138
Total character requirements		649,510,000
Bits per character	X	8
Total bit storage requirement		5,196,100,000

Identification and Formulation of the Problem

Ostrofsky suggests the use of a matrix, such as shown in Figure 5, as a tool in identifying needs in the context of the production-consumption cycle. Identification of the problem serves to establish the bounds of the needs and requirements of the system under design. Each phase of the production-consumption cycle is considered and the activities or work items that pertain to each are listed in as much detail as necessary to complete the designer's ideas (24:35).

	Inputs		Outputs	
	Intended	Environment	Desired	Undesired
Production				
Distribution				
Consumption- Operation				
Retirement				

Figure 5. *Activity Analysis for Problem Formulation (9:36)*

During each phase in the life cycle, outputs and the inputs necessary to achieve them are considered. The desired outputs may not always be achievable and the undesirable outputs may not always be avoidable. Inputs can be those actions, items, or processes which are intended to start the process, or they can result from the environment that the system will exist in and effect this phase of the life cycle. Osterofsky's matrix is a tool used to identify the inputs and outputs of each iteration of Figure 6.

These boundary setting elements establish the framework in which the product's or process' life cycle occurs. In terms of the production-consumption life cycle, the four phases of the cycle are; production, distribution, consumption/operation, and retirement.

Production Phase

Production involves the transformation of goods and services into something more useful (24:9). The product in this study is defined as accessible storage capacity. The

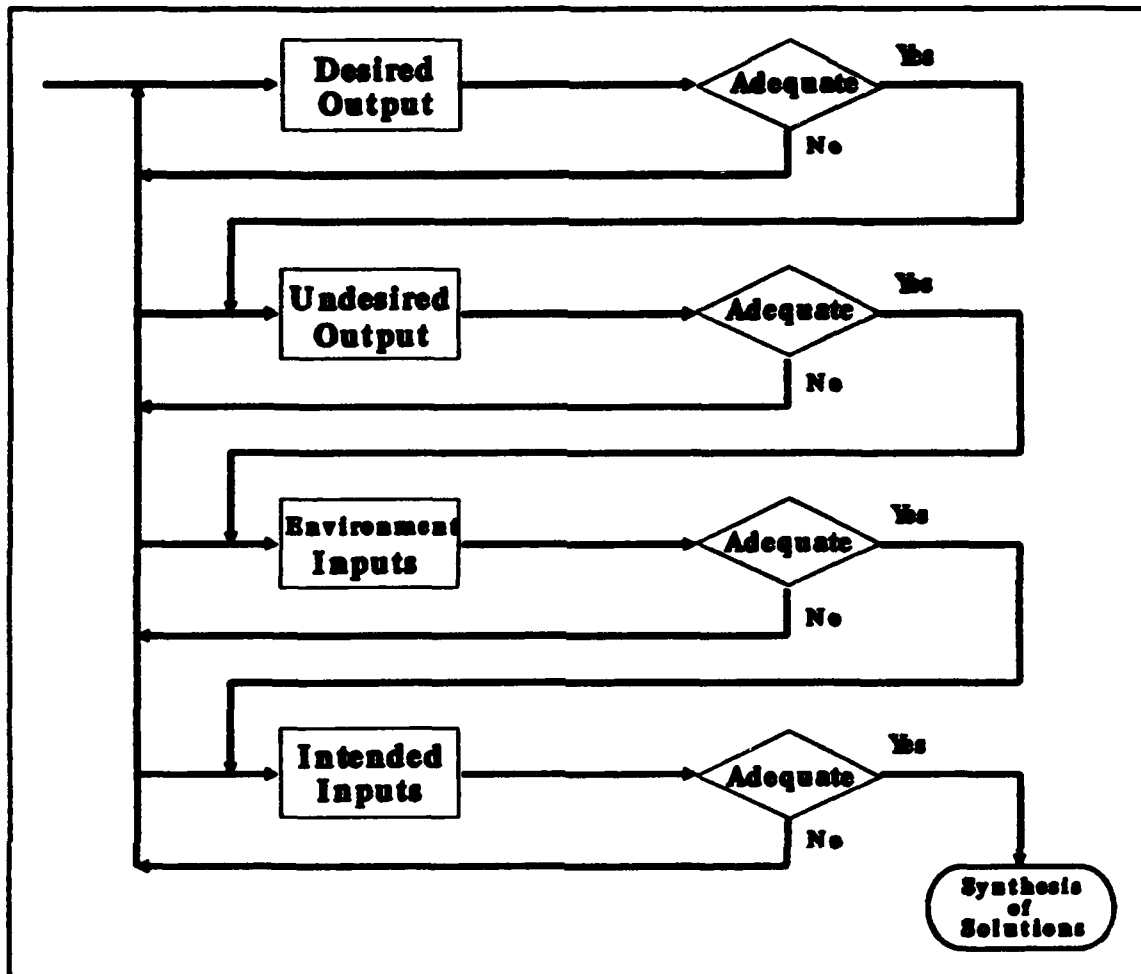


Figure 6. *Identification and Formulation of the Problem*
(24:36)

production process is the transformation of the intended inputs into a data output. A component of the data output is the capacity it takes to make the data available to the GTN. An analysis of the production activity is shown in Table 9.

Distribution Phase

Distribution is the transfer of the product to the locations where it will be used (24:11). The capacity in

Table 9. Production Activity Analysis

<i>INPUTS</i>	
<i>Intended</i>	<i>Environmental</i>
1. Volatile memory	1. Compatible with current GTN
2. Static memory	2. High probability of compatibility with future GTN systems
3. Digital data	
<i>OUTPUTS</i>	
<i>Desired</i>	<i>Undesired</i>
1. Low error rates	1. Rapid obsolescence
2. High level of responsiveness	
3. Digital data	

the designed system must be made available by some means to other information systems within the GTN. These other processes will need to store specific data elements of the information they contain and to access transportation data already contained in the developed storage system. Table 10 contains an analysis of the distribution activity.

Table 10. Distribution Activity Analysis

<i>INPUTS</i>	
<i>Intended</i>	<i>Environmental</i>
1. Transmission medium	1. GTN connectivity
	2. Network protocols
<i>OUTPUTS</i>	
<i>Desired</i>	<i>Undesired</i>
1. Readily accessible storage system	1. Low Security

Consumption/Operation Phase

In this phase, the product is accomplishing the needs for which it was produced (24:11). The storage repository

produced is storing data transmitted by other systems in the GTN and is sending data to those other systems requesting it. This phase's activities are shown in Table 11.

Table 11. *Consumption/Operation Activity Analysis*

<i>INPUTS</i>	
<i>Intended</i>	<i>Environmental</i>
1. Storage capacity available on demand	1. Transmission medium
2. Shipment data available on demand	2. Severe weather
<i>OUTPUTS</i>	
<i>Desired</i>	<i>Undesired</i>
1. Adequate memory to store data on all active shipments	1. Excessive memory
2. Surge capacity for extra shipments generated during contingencies	2. Duplicate records
3. Expanded shipment data	
4. Robust data	
5. Secure data	

Retirement Phase

Retirement is the withdrawal of the system from its intended purpose (24:33). It is the final phase in the product's life. The capacity of the developed storage system will eventually be used by data sent by another system in the GTN. These other information systems will use the data stored in the repository until the shipment the data represents is no longer active. The data will then be removed to off line storage, which replenishes the capacity

of the system. The activities of this final phase are listed in Table 12.

Table 12. Retirement Activity Analysis

INPUTS	
<i>Intended</i>	<i>Environmental</i>
1. Data disks	1. Connectivity to I/O device
2. Buffer memory at I/O device	
3. I/O device	
OUTPUTS	
<i>Desired</i>	<i>Undesired</i>
1. Data is stored, transmitted, and eventually transferred to off line storage	1. Data remains after shipment reaches consignee
	2. Lost data

Synthesis of Solutions

This third stage of the feasibility study pieces together the activities of the production/consumption cycle. It integrates those activities within defined boundaries and with a sequence of functions to meet the needs established during the cycle (24:45,46,54). This process is depicted in Figure 7.

Ostrofsky defines a concept as a "basic approach to the solution of the design-planning problem." It is a combination of the subsystems that contain the activities necessary to form the total system functions required to solve the design problem (24:46-47). Any all inclusive listing of concepts may contain some approaches which, on the surface, may appear to be quite infeasible. However,

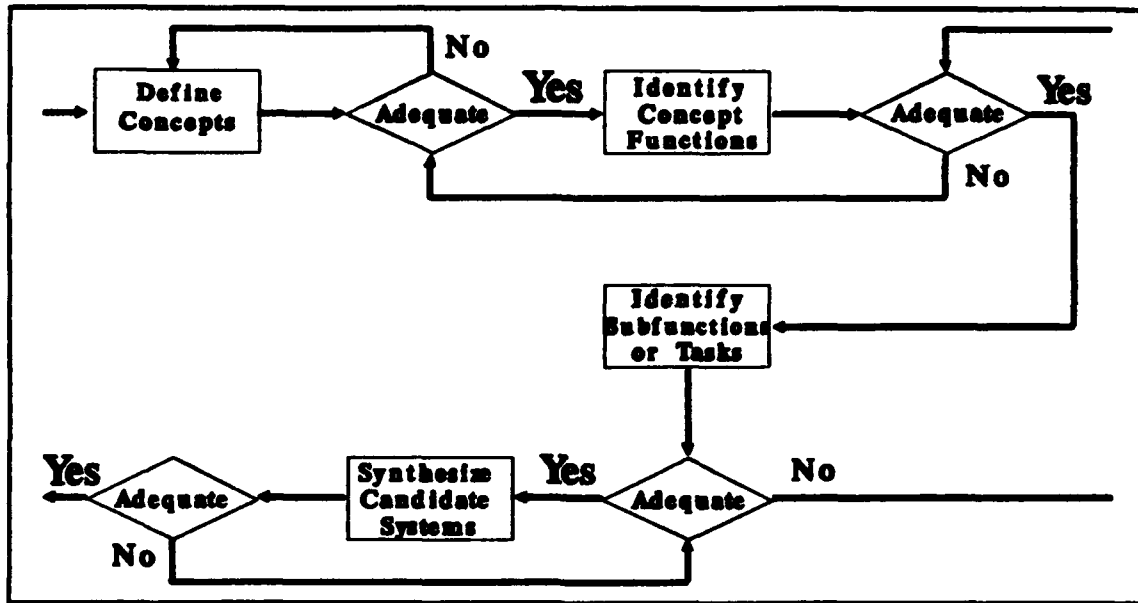


Figure 7. *Synthesis of Solutions* (24:46)

discarding any concept prior to a thorough evaluation increases the risk that the chosen design will not be the optimal solution (16:26).

Since the optimal system may in fact be at some level of storage capacity less than that of the worst case basis, three levels of required capacity were deterministically established in an attempt to ensure the capture of the optimal system. All of the following concepts meet the identified need:

1. Utilize a system with 100 percent of the worst case storage requirements and a guided transmission medium.
2. Utilize a system with 100 percent of the worst case storage requirements and an unguided transmission medium.
3. Utilize a system with 100 percent of the worst case storage requirements and both guided and unguided transmission mediums.

4. Utilize a system with 75 percent of the worst case storage requirements and a guided transmission medium.
5. Utilize a system with 75 percent of the worst case storage requirements and an unguided transmission medium.
6. Utilize a system with 75 percent of the worst case storage requirements and both guided and unguided transmission mediums.
7. Utilize a system with 50 percent of the worst case storage requirements and a guided transmission medium.
8. Utilize a system with 50 percent of the worst case storage requirements and an unguided transmission medium.
9. Utilize a system with 50 percent of the worst case storage requirements and both guided and unguided transmission mediums.

In order to derive the greatest number of potential solutions to the problem, concepts must be "broken down into their corresponding subsystems functions and activities" (24:257). Each subsystem is an identifiable part that contributes to the function of the larger system. It is composed of many activities and their alternatives. Each activity contributes to the creation of capacity and the provisioning of data to the system.

Candidate systems are created by grouping together subsystem activities or their alternative activities from each subsystem function. As Figure 8 indicates, this could result in many possible systems. However, it is an attempt to capture the best system within the solution set to the stated need (24:47).

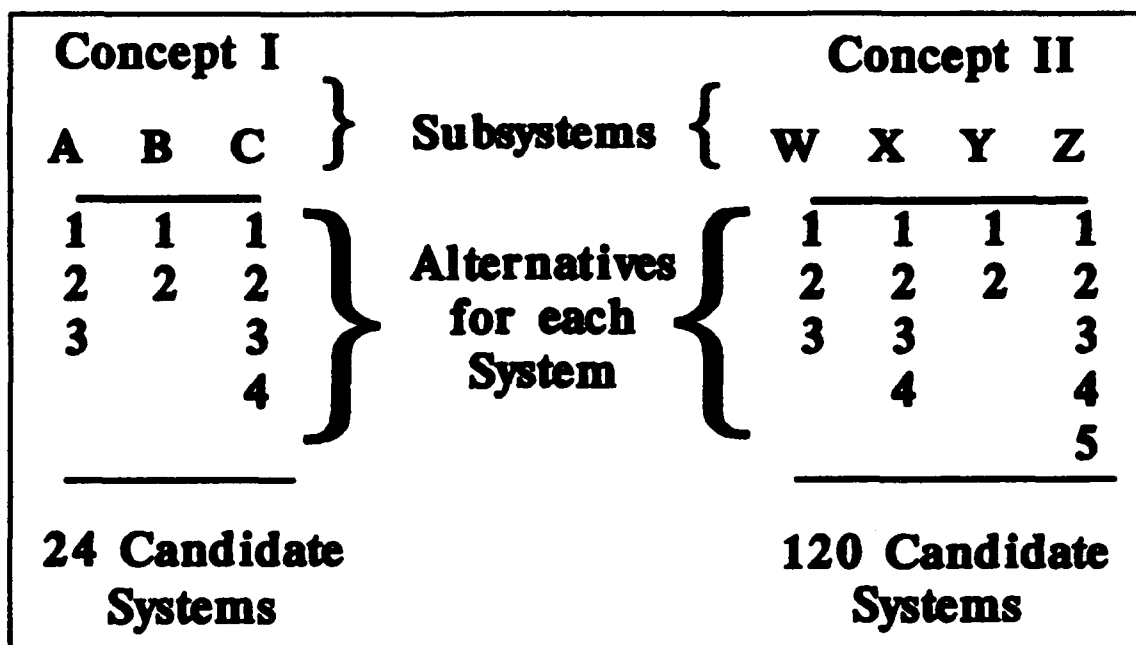


Figure 8. *Formulation of Candidate Systems (24:48)*

All nine concepts generated provide the GTN with some degree of the worst case on-demand storage capacity and access to stored data. Each differs from the next only in terms of the attributes of each of the activities within the concept. Table 13 lists these activities. The process for each is the same, but the effects of different transmission systems and packet switching protocols may be more or less desirable than alternate systems.

Any existing system, systems being expanded, new systems or data networks will become DDN subscribers (13). The DDN is a data transmission network created to link computers and other equipment. It utilizes both unguided and guided mediums (10:3-4,5-3,5-4).

Table 13. Concept Candidate Systems

A. Type of Transmission Medium

1. Twisted Wire Pair
2. Coaxial Cable
3. Telephone Line
4. Fiber Optics
5. Radio
6. Microwave
7. Satellite
8. Any of the 5040 combinations of 1 to 7

B. Source of Transmission Medium

1. Government owned
2. Commercially leased
3. Commercial common user
5. Combination of 1 and 2
6. Combination of 1 and 3
7. Combination of 2 and 3
8. Combination of 1, 2, and 3

C. Type of Line Service

1. Switched
2. Leased
3. Combination of 1 and 2

D. Type of External Network Service

1. Virtual circuit
2. Datagram
3. Combination of 1 and 2

E. Type of Internal Network Service

1. Virtual circuit
2. Datagram
3. Combination of 1 and 2

Concepts I, II, IV, V, VII, and VIII all exclude mixing of transmission mediums and were subsequently removed from further consideration. Concepts III, VI, and IX are separated by only the amount of storage capacity each

requires as stated in terms of a percentage of the worst case data storage requirement. Combinations of each of the alternatives resulted in the following number of candidate systems:

A		B		C		D		E	
5047	X	8	X	3	X	3	X	3	= 1,090,152 candidate systems

That is, there are 1,090,152 candidate systems that apply at each level of required storage capacity. These systems must be examined for evidence of physical, economic, and financial infeasibility.

Screening of Candidate Systems

The more numerous the candidate systems, the greater the probability that the optimal system is contained within the set. These systems must be scrutinized to assure they have at least the potential to be feasible. No system should be eliminated unless that candidate can be shown to be physically, economically, or financially infeasible. If there is any doubt concerning a particular candidate system, that system should remain in the set of candidates for future evaluation (24:55,57).

Physical realizability is the ability to actually achieve the combinations of components listed in the candidate systems. Those combinations which are physically incompatible must be eliminated from consideration (24:57,58). All combinations listed were found to be physically realizable.

Any candidate system being considered must be able to provide a sufficient return on the investment of resources necessary to achieve its completion. As Osterofsky states, "The total resources required to complete the design of the candidate system must be less than the value received from its completion" (24:58). Mixing types of line service and internal and external network service is not economically feasible. Connectivity encompassing both switched and leased line service from the storage repository to the GTN will incur the higher costs associated with leased service and perform no better than a switched connection. The same premise holds true for mixing virtual and datagram service within the internal or external network component. Similarly, an external datagram coupled with an internal virtual circuit service at the network interface higher costs without providing the greater benefit of sequential delivery of packets of data. Those components not economically feasible are listed in Table 14.

Table 14. *Economic Impracticalities*

Component	Incompatible With
C3	C1-2
D3	D1-2, E1-3
E3	D1-3, E1-2

A lack of financial resources can eliminate even the optimal system from consideration. Given the demand for

intransit visibility of airlifted equipment and personnel during Operations Desert Storm and the effect of that demand on the development of transportation information systems, development of a supporting data repository could well be within funding constraints at the Air Force or major command level. Implementation would still depend on the willingness to develop the system and the availability of funds for other priority projects.

V. Observations and Recommendations

The purpose of this study was to determine a set of useful solutions to the problem of storing and processing significant increases in the amount of data being generated by transportation data processing systems within the Department of Defense. The literature suggests the increase is due to the expansion of the Joint Operational Planning and Execution System to meet operational requirements. JOPEs and the Global Transportation Network, with its service specific transportation information systems, are key elements in providing intransit visibility on troops and equipment deployed during contingencies. The requirement for intransit visibility is the driving factor behind the increased level of data that JOPEs requires.

The methodology used was particularly well suited to the investigation of the problem. As a design tool and instructional aid, it provided the framework for systematically thinking through the problem. Its iterative nature never provided the singularly best outcome at any stage of the design problem. Rather, it yielded an array of solutions to ensure the capture of the optimal solution. This solution set was arrived at by assessing needs within limits and boundaries imposed by the examination of activities which any feasible solution must be able to accomplish.

Observations

Analysis of the production/consumption cycle indicated that the design problem not only had to consider storage capacity size, but also the medium by which the capacity would be transferred to the GTN. A worst case basis for data generation yielded a storage requirement for approximately 650 Mega bytes. In an attempt to bound the normal operating level and surge requirements, the parameters of 50, 75, and 100 percent of the total derived capacity were deterministically set. Both guided, unguided, and combinations of both medium types were considered to transfer the capacity to the GTN.

Over one million potential solutions to the problem were formulated from combining the different attributes of the candidate system. Reducing this number by removing those solutions based on infeasible physical, economic or financial components proved difficult. There are over 5,000 possible combinations of seven different transmission mediums. Although each may have different performance characteristics, all are physically realizable either individually or in some combination. For example, it may be improbable that the developed storage system will be directly linked to the GTN through satellite technology, but it is not impossible. In fact, it may prove probable that satellite technology in combination with some other medium or mediums will be used to provide connectivity to some parts of the GTN.

Only three components could be determined economically infeasible. Yet, this was sufficient to reduce the number of candidate systems to just over 300,000. The financial feasibility was assumed, given the interest in intransit visibility at the major command level.

Table 15 lists some of the properties of media to be considered in selecting the most suitable medium for a given application. All of these media are present to some degree within the DDN.

Table 15. *Aspects of Data Communication Media (27:60)*

	Wire	Coaxial Cable	Fiber Optics	Micro- wave	Radio	Satellite
Avail- ability	Good	Good	Good	Good	Fair	Fair/Good
Expand- ability	Fair	Good (local)	Good	Good	Good	Good
Errors	Fair	Good	Good	Fair	Fair	Fair
Security	Fair	Good	Good	Fair	Fair	Fair
Distance	Good	Poor	Good	Good	Good	Good
Environ- ment	Fair	Good	Good	Fair	Fair	Fair

The directive that all DOD data communication systems to use the DDN imposes constraints on the selection of the type medium to be employed. Although, the optimal solution may lie outside of the DDN, the effect of its constraints on the number of candidate systems generated is worth noting.

Since the DDN operates as an internal and external datagram network service, this effectively removes from consideration the two components of virtual circuit internal and external network service and reduces the prospective number of candidate systems to 80,752. Since the DDN is comprised of mainly satellite, microwave, wire line, and some fiber optics from a combination of sources, consideration of only these components would make a substantial reduction of the prospective systems to 48 candidates.

The range of candidate systems offered by application of Osterofsky's methodology certainly has the greater potential for inclusion of the optimal system. Yet, the practical constraints of the DDN must, at this stage, be ignored, since the optimal system may well lie outside the conditions imposed by the DDN. However, it is equally impossible to rule out the feasibility of the DDN parameters to contain the optimal storage system.

Recommendations

Osterofsky states that when a large number of candidate systems escape the synthesis of solutions with only very few being eliminated in the screening process, the designer should reexamine the earlier steps in the feasibility study. A more critical examination of these steps can eliminate those candidates that do not meet the more narrowly defined

requirements. However, this also increases the risk of elimination of the optimal solution.

A more practical method to proceed with further research may be to accept the limitations of the DDN, in concept. That is, approach the preliminary activities phase of the morphology by grouping by attributes. By starting with those candidates not in common with the DDN, attention can be focused on the degree of acceptability of the disadvantages of each. Radio, for example, may offer sufficient disadvantages to warrant its exclusion. The designer can then return to the earlier phases with a view to more narrowly defining concepts and candidates with this singular component in mind rather than the entire spectrum of candidate system components generated during the feasibility study.

Further study is needed to determine the exact amount of storage required to facilitate the demands of the GTN. The 650 Mega bytes of storage required by the worst case scenario may be sufficient for determining the general feasibility of a particular system. However, it lacks the specificity expected in defining optimal systems. Current transportation data processing activities expected to be within the GTN should be statistically examined to determine a more precise level of data requiring transfer and storage.

The DDN's current media operating characteristics should be analyzed to validate any constraints that system may impose on the GTN. For example, the DDN continues to

operate satellite feeds even though optical fiber is available to Europe and the Far East. This may be more a function of redundancy requirements than a stagnation of functional growth due to budgetary considerations, but the implications for the performance of the GTN should still be examined.

Summary

A centralized data storage repository of sufficient capacity to handle the projected increased demands placed on the GTN by JOPES is feasible. There is a lack of clarity concerning the actual design of this proposed system due to a significantly large number of possible candidates of which it could, conceptually, consist. Further research and application of Osterofsky's preliminary activities will reduce the number of potential candidates to the optimal solution.

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Vita

Captain Philip L. Isbell was born 25 July 1952 in Wigan, England. He graduated from San Diego State University, San Diego, California, in 1981 with a Bachelor of Science Degree in Business Administration with a concentration in management. He received his commission through the Reserve Officer Training Corps and reported to active duty in March 1982. His first assignment was to the 443 Transportation Squadron, Altus AFB, Altus, Oklahoma, where he performed duties as the Vehicle Maintenance Officer and Vehicle Management Officer. In 1983, he was reassigned to the 316th Aerial Port Squadron, Yokota Air Base, Japan, where he served as an Air Terminal Operations Center Duty Officer, Assistant Squadron Operations Officer, Chief of Mobility Plans and Programs, and Detachment Commander, 316APS Det 1, Misawa Air Base, Japan. In September 1986, he reported to the 5th Mobile Aerial Port Squadron, Royal Air Force Mildenhall, United Kingdom. He performed duties as the OIC, Aerial Delivery, Chief, Combat Readiness, and Squadron Operations Officer until entering the Air Force Institute of Technology in June 1990.

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1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE SEPTEMBER 1991	3. REPORT TYPE AND DATES COVERED MASTER'S THESIS
4. TITLE AND SUBTITLE MILITARY STANDARDIZED TRANSPORTATION AND MOVEMENT PROCEDURES DETAILED MANIFEST DATA STORAGE REQUIREMENTS			5. FUNDING NUMBERS
6. AUTHOR(S) Philip L. Isbell, Captain, USAF			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Air Force Institute of Technology, WPAFB, OH 45433-6583			8. PERFORMING ORGANIZATION REPORT NUMBER AFIT/GLM/LSP/91S-32
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)			10. SPONSORING / MONITORING AGENCY REPORT NUMBER
11. SUPPLEMENTARY NOTES			
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution unlimited			12b. DISTRIBUTION CODE
13. ABSTRACT (Maximum 200 words) The purpose of this study was to develop a set of useful solutions to the problem of storing and processing data generated by transportation data processing systems within the Department of Defense. The amount of data within the Global Transportation Network (GTN) will significantly increase due to the expansion of the Joint Operational Planning and Execution System (JOPES). Intransit visibility of troops and equipment during contingencies is the driving factor behind the increased level of data required by JOPES. The methodology used conducted a needs analysis of the problem, which was defined as an insufficient amount of storage capacity for the amount of anticipated data required by JOPES. A feasibility study was completed that organized relevant information into a more meaningful analysis. A solution set was derived by assessing needs within boundaries imposed by the activities which any system must perform to solve the stated problem. The cyclical nature of the analysis indicated that the medium by which the capacity would be transferred to the GTN must also be considered. Over 300,000 potential solutions to the problem were formulated. Further research into the methodology's preliminary activities will reduce the number of potential candidates to the optimal solution. (25)			
14. SUBJECT TERMS * Air Transportation, * Information Systems, * Information Transfer, Experimental Design, Thescs.			15. NUMBER OF PAGES 78
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UL

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